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Spline Instability in High Speed Rotors

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Stiffness and damping coefficients have been identified experimentally for loose spline couplings used in high speed rotating machinery. This is believed to be the first time such coefficients have ever been identified experimentally. Loose spline couplings have a destabilizing effect on rotor systems. The spline coefficients are therefore needed at the machinery design stage to predict whether the rotor system will remain stable, within its operating envelope, when fitted with a particular spline coupling design.

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SPLINE INSTABILITY IN HIGH SPEED ROTORS

Final Report

Jorgen L. Nikolajsen

March 30, 1991

U.S. ARMY RESEARCH OFFICE

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### Statement of Problem Studied

Loose spline couplings are used to transmit torque, for example between the power turbine shaft and the reduction gearbox in a gasturbine engine. However, loose splines have a destabilizing effect on the rotor systems in which they are included. The objective of this work is to identify the stiffness and damping coefficients of loose splines for use in rotor stability analyses at the design stage. The spline stiffness and damping coefficients are identified by incorporating the spline in a flexible rotor system and using experimental modal analysis to measure the vibration characteristics of the rotor system, i.e., damped natural frequencies, mode shapes, and modal damping. A computer program is also set up to predict those same vibration characteristics of the rotor. Identification of the spline coefficients is then achieved by adjusting the coefficient values in the computer program to provide a perfect fit between the predicted and the measured vibration characteristics.

### Summary of Most Important Results

Stiffness and damping coefficients have been identified for several different spline geometries showing the effect of spline diameter and length and number of teeth on the coefficient values. Spline coefficients have also been identified for several different operating conditions such as rotor speed, torque transmitted, rotor misalignment and level of spline lubrication. The coefficients are tabulated and shown in graphical form with error bounds in Publication #3, referenced in this report. Publication #3 will be forwarded to the ARO in May, 1991.

This project represents the first attempt ever to identify loose spline coupling coefficients experimentally. Publication #3 also provides recommendations for adjusting the experimental procedure to improve the accuracy of the coefficient values. However, the coefficient values shown in Publication #3 are considered adequate for rough preliminary design studies of advanced turbomachinery rotordynamics if used with due caution.

Publication of these results in a scientific journal is anticipated in the near future. The expected long term impacts of this work are (1) a wider use of simple, reliable, inexpensive spline couplings in turbomachinery and (2) retrofit of existing unstable machinery with 'stable' splines.

### Publications and Technical Reports Published

1. Rombado, G., "Development of Experimental Apparatus and Procedures for Measurement of Rotordynamic Coefficients of Loose Spline Couplings", M.S. Thesis, Texas A&M University, May 1989.
2. Nikolajsen, J.L., Rombado, G., and Park, S.K., "Identification of Loose Spline Couplings. Part 1 - Experimental Apparatus", The International Symposium on Advanced Computers for Dynamics and

Design, Tsuchiura, Japan, Sept. 1989.

3. Park, S.K., "Determination of Loose Spline Coupling Coefficients of Rotor-Bearing Systems in Turbomachinery", PhD Dissertation, Texas A&M University, May 1991.

Participating Scientific Personnel

Jorgen L. Nikolajsen, P.I.

Sang K. Park, earned PhD in Mechanical Engineering

Gabriel Rombado, earned M.S. in Mechanical Engineering

Reportable Inventions

None.